6-PART V.GL
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GUIDELINE FOR THE HYDROGEOLOGIC ASSESSMENT OF PROPOSED LANDFILLS UNDER THE ENVIRONMENTAL PROTECTION ACT, PART V

Suggestions for the Assessment of Off-site Impact in Hydrogeological Reports Submitted to the Ministry for Proposed Landfills

Monitoring and Contingency Plans for Landfill Sites

The Establishment of Safety Margins in the Assessment of Landfill Sites

The Control of Groundwater Development in the Vicinity of Landfill Sites

Working Group V
Water Management Steering Committee
Ministry of the Environment and Energy

Copies available from the Waste Management Branch

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1.0 SCOPE AND INTENT OF GUIDELINE

This guideline is a support document to Policy 15-08: "The Incorporation of the Reasonable Use Concept into the Groundwater Management Activities of the Ministry of the Environment and Energy", September,1986, revised March 1993. The "Reasonable Use" policy limits contaminant discharge from disposal sites to levels that the Ministry considers to be acceptable and addresses the need for incorporating monitoring plans, contingency plans, and safety margins into proposals for new and expanding disposal sites. This guideline addresses only the protection of existing or potential groundwater supplies. It applies primarily to the hydrogeologic assessment of landfill sites normally performed in support of applications under Part V of the Environmental Protection Act; but also relates to other Ministry activities. Policy 15-10, "The Resolution of Groundwater Quality Interference Problems" addresses the Ministry approach to the abatement of groundwater contamination that has been caused by activities that were not done under a Certificate of Approval issued by the Ministry (eg. contamination from spills, closed landfills).

Section 2.0 of this guideline addresses contaminant discharges from landfill sites and the determination of how these discharges will be measured and assessed by the Ministry. Section 3.0 addresses monitoring and contingency plans, while Section 4.0 addresses the establishment of safety margins. The last section, Section 5.0, addresses possible legal controls on the development of groundwater in the vicinity of landfill sites.

This guideline was prepared for the use of Ministry staff, experienced in hydrogeology, who are routinely involved in the assessment of proposals for landfills and applicants in consultation with Ministry staff. It presents the Ministry views on the various procedures that might be followed in assessments and the issues that should be addressed. It is not intended as an instruction or design manual, but assumes a working knowledge of hydrogeology and an understanding of related Ministry policy and guidelines, and in particular, Policy 15-08 the "Reasonable Use" Policy and Policy 14-15, the "Engineered Landfill" Policy and the technical guidelines: "Advice to Applicants and to Consultants in Preparing Hydrogeologic Reports for Proposed Landfill Sites" and "Technical Considerations in the Assessment of Hydrogeologic Reports".

The field of landfill design is relatively new and the state-of-the-art is undergoing rapid change as methodology and technology develop. Therefore, the guideline addresses performance or results rather than methodology. For example, the information that must be gathered by a monitoring plan, or its objectives, are specified by the

Ministry, but the number of monitoring installations that would be required to gather this information should be determined by the applicant. The Ministry cannot specify a minimum number of bore holes, water quality samples, etc., that would apply to all landfill sites. Variations in hydrogeology, waste composition and landfill size are too great to permit this approach. Instead, judgements will be made on a case-by-case basis in accordance with the advice presented in this and other relevant Ministry policies and guidelines.

As noted in the "Advice to Consultants" guideline, guidance on the scope and sophistication of the site investigation will be provided on a case-by-case basis by Ministry personnel in discussions with an applicant. The Ministry may not always agree with the applicant's prediction of environmental impact. In such cases, such a proposal may be accepted if significant environmental damage will not result and the applicant provides a monitoring plan that will support the prediction and a contingency plan for implementation *if the prediction is shown to be in error.*

In view of the uncertainties involved in landfill design it is the general policy of the Ministry to select sites that are naturally protective, where failure will have a minimum impact on the water resources of the Province.

2.0 SUGGESTIONS FOR THE ASSESSMENT OF OFF-SITE IMPACT IN HYDROGEOLOGICAL REPORTS SUBMITTED TO THE MINISTRY FOR PROPOSED LANDFILL SITES.

2.1 INTRODUCTION

The Ministry "Reasonable Use" Policy states that the Ministry will protect reasonable uses of groundwater on property adjacent to waste disposal activities. It outlines the procedures to be used in determining the reasonable use of groundwater on "Adjacent Property" (as defined in the Policy) and specifies the procedure to be used in determining the levels of contaminants that may leave a site. In assessing a proposed disposal site, or a site wishing to expand, a proponent must provide an estimate of potential contaminant discharge that shows that the contamination from the site will meet the limits specified by the "Reasonable Use" Policy. Three basic steps are required to make this estimate. These are:

1. to identify the subsurface unit or units that must be protected in order to meet the requirements of the Reasonable Use Policy; (This document is concerned only with the protection of groundwater. Advice on the protection of surface water, utilities, etc., should be obtained on a case-by-case basis from Regional staff.)

2. to identify the particular contaminant(s) that is of most concern (i.e., the "critical contaminant"); and

3. to estimate the maximum impact of the critical contaminant on the unit(s) identified in (1) above.

The following discussion presupposes that an adequate understanding of groundwater flow at the site has been achieved. Flow path analyses must be completed before a useful estimate can be made of the impact of contaminant discharge on the groundwaters.

2.2 THE IDENTIFICATION OF THE SUBSURFACE UNIT OR UNITS THAT MUST BE PROTECTED

As indicated in the "Reasonable Use" policy, the Ministry objective is to protect the present and potential reasonable uses of groundwater on adjacent property (i.e. reasonable sites for water wells that will produce water meeting the Reasonable Use limits). To accomplish this, the groundwater resource and its uses must be described and the means used to obtain this resource must be understood. The applicant should determine the distribution and characteristics of the subsurface unit(s) that yield water, the quality and quantity of the groundwater that is produced or could be

produced, the present and potential uses of this groundwater resource, and the types of wells that are commonly used or would reasonably be expected to be used to develop this resource.

Based on the assessment of these factors, the applicant should identify; the subsurface unit(s) that constitute the water resource and would have to be protected in order to meet the requirements of the "Reasonable Use" policy.

In most cases, the water resource that is to be protected will begin at the site boundary or the boundary of a Contaminant Attenuation Zone. However, in some cases, the presence of highways, streams, topographic constraints, etc., may indicate that the water resource to be protected is at some distance from the site boundary.

The estimate of off-site impact and the development of the monitoring program require this identification. This is discussed further in Sections 2.4 and 3.7 of this guideline.

There are also a number of other factors that should be considered in determining the unit(s) that must be protected in the vicinity of a proposed landfill. These are as follows:

1. The Ministry will not necessarily judge the acceptability of a contaminant discharge on the basis of contaminant levels in the most contaminated unit in the subsurface unless these levels will impair the present or potential Reasonable Use of that water resource.

2. Ontario Regulation 612/84 pertaining to water well construction applies primarily to the construction of new wells and cannot be used to require owners to modify older domestic wells, only to maintain them. The importance of this facet of the regulation is that it will not allow consideration to be given to requests that the Ministry have well owners redrill or replace their well supplies in order to allow an increase in contaminant levels at the waste disposal boundary.

3. The following requests will only be considered in the most exceptional circumstances:

    a. Requests to designate aquifers as sole source (the only practical source of water) to enforce more stringent well construction design practices beyond those provided in O.R. 612/84; (Section 5.0), or,

b. Requests to restrict development to specific aquifers in order to accommodate or permit off-site aquifer contamination (Section 5.0).

2.3 THE SELECTION OF THE CRITICAL CONTAMINANT FROM A LANDFILL

2.3.1 Introduction

The critical contaminant in a contaminant plume is the particular contaminant which has reached, or has the greatest potential to reach unacceptably high levels at a point of potential groundwater use. In order to determine if a landfill site will comply with Ministry limits on contaminant discharges, the critical contaminant must be identified and its concentration in the unit(s) that must be protected, estimated. This is the responsibility of the applicant.

The critical contaminant at any waste disposal site will depend on the characteristics of the waste itself, and on the contaminant attenuation characteristics of the hydrogeologic system through which the leachate migrates. For example, the critical contaminant in the leachate from a landfill site in silt may be quite different than in a similar leachate from a site in sand and gravel, because of the differences in the attenuating properties of the two media. The critical contaminant may also vary depending on the residence time in the subsurface and the present or potential use and quality of the water resource that is being protected. Thus, it will not always be possible to identify the critical contaminant with certainty in the site assessment program and it may be necessary to make a preliminary selection of one or more potential candidates for use until additional monitoring data are available.

Determination of the critical contaminant for a particular waste at a proposed disposal site is a technically complex problem. The Ministry does not have a list of acceptable or preferred methods for identifying the critical contaminant and the literature on this subject is sparse. Given these circumstances, the Ministry intends, for the present, to rely on the initiative of proponents to develop procedures for establishing critical contaminants and will assess these methods on a case-by-case basis. However, a conservative approach must be taken and an estimate made based on a thorough investigation of the site and what research is available. Ultimately, a predictive monitoring program will test the selection of the

critical contaminant and indicate whether modifications are necessary. At an existing site, with a well-developed contaminant plume, the critical contaminant should be more easily determined.

2.3.2 General Comments

1. Where a critical contaminant is particularly difficult to sample or to analyze, it is acceptable to monitor a related indicator contaminant that can be shown to vary directly as the critical contaminant.

2. Some persistent contaminants are unacceptable in the environment at concentrations as low as a few micrograms per litre or less. Where such contaminants are present in wastes, even if in very small amounts, it will be very difficult to find landfill sites where attenuation is adequate. Under these circumstances other methods of disposal should be considered. Therefore, it may facilitate a site assessment and allow the early rejection of unsuitable sites or wastes if the applicant first makes a preliminary estimate of the amount of attenuation that will be required to reduce the concentration of the critical contaminant to acceptable levels. It would then be a relatively simple matter to determine if the prospective site is likely to provide this amount of attenuation, or to judge if the particular waste is amenable to landfill disposal.

3. In some instances, indicator parameters or "rules of thumb" have been used in place of the critical contaminant to assess site suitability. For example, an increase of 50 mg/L chloride has been used for this purpose. This approach was based on the assumption that other parameters in the leachate would not reach unacceptable levels provided that the increase in the concentration of chloride does not exceed 50 mg/L. It is felt that this approach can be improved upon substantially. It is no longer recommended, except perhaps for use in an initial check on a proposed site.

2.4 METHODS OF ESTIMATING THE IMPACT OF CONTAMINANTS FROM LANDFILL SITES

2.4.1 Introduction

The state-of-the-art is such that the Ministry cannot rely solely on a prediction of contaminant levels in

assessing the suitability of a proposed landfill. There must also be monitoring programs and contingency plans to ensure the protection of the environment. However, despite their lack of certainty, quantitative estimates of potential contaminant levels are useful and necessary in a site assessment.

This section of the guideline addresses methods that can be used to estimate landfill site impact. It is divided into three parts. The first part deals with methods for estimating contaminant attenuation resulting from hydrodynamic dispersion or dilution (ie. mixing groundwater that has been contaminated by leachate with groundwater that has not been contaminated by leachate), the second part deals with methods for estimating the attenuation of reactive solutes, and the third part provides some general comments on estimating site impact.

2.4.2 Methods of Estimating Attenuation that Results from Hydrodynamic Dispersion

Several approaches can be used to estimate potential attenuation resulting from hydrodynamic dispersion at a proposed site. The approach, or approaches, that are used will depend on the particular site and the availability of data. Some of the approaches that can be considered are:

1. An estimate, based on mixing groundwater flowing under the landfill with leachate contaminated groundwater produced by the landfill. The estimate can be based on consideration of advective, dispersive and diffusive processes along flow paths;

2. An estimate based on comparing the amount of water that is recharged in the areas upgradient and downgradient from the landfill with the leachate contaminated groundwater produced by the landfill. This would be accomplished by comparing these areas to that of the landfill and considering their relative infiltration rates;

3. Assuming the same amount of hydrodynamic dispersion or mixing that is provided by a site in a similar hydrogeologic setting will be provided at the site that is being assessed.

The first approach requires, among other things, estimates of hydraulic conductivity and/or dispersivity and will, therefore, yield estimates of attenuation

which, even in sophisticated assessments, could be in error by as much as 5 times.

In using approaches one and two a non-conservative maximum amount of attenuation will be calculated if complete mixing in the aquifer is assumed. It is recognized that dispersion cannot always be properly considered.

The third approach, although potentially the most accurate, is an empirical approach and should be used with caution. This approach should generally be used in conjunction with approach one or two. It will require information on site history, detailed hydrogeologic conditions and historical data on leachate strength that may be difficult to obtain.

It is better to determine this attenuation factor from a stable plume which has been clearly described. Comparison of concentration versus travel distance from several points along a flow path in such a plume will allow some understanding of the reliability of the estimate.

Where possible, several methods of calculating the attenuation that results from hydrodynamic dispersion should be used on each site. A range of the possible amounts that might be expected to occur should be provided in the applicant's proposal and the results compared and discussed.

2.4.3 The Attenuation of Reactive Solutes

This section addresses the attenuation of contaminants by mechanisms other than by hydrodynamic dispersion. The attenuation of reactive solutes can be estimated by:

1. Assuming the same amount of attenuation that is provided by a site in a similar hydrogeologic/ geochemical setting will be provided at the site that is being assessed.
2. Estimating attenuation based on reactive solute models and values of various parameters from the literature.

Estimates based on measurements from a site in a similar hydrogeologic/geochemical setting, either from a nearby landfill or in a different part of the same landfill, are considered to be more reliable than estimates based on measurements from other sites or in laboratory tests recorded in the general literature.

Predictive mathematical modelling of reactive transport has the potential for a high degree of error, and estimates of attenuation based on this method of assessment are not acceptable unless they incorporate an appropriate margin of safety (Section 4.2) or they are strongly supported by a proper site assessment.

2.4.4 General Comments

1. In reviewing hydrogeologic assessments, it is important to ensure that the data form a part of a coherent pattern in a well understood hydrogeologic system.

2. In order to estimate the impact of a proposed landfill on the groundwater resource beneath the adjacent property, it is necessary to calculate the flux of contamination through a subsurface unit(s) that has been carefully selected to most accurately reflect the impact of the site on this water resource. The unit(s) that is selected for this purpose will generally be identical to that identified in Section 2.2. However, where appropriate, a simplified approximation of the same unit(s) may be used for the purposes of this estimate. In making this estimate it is not acceptable to assume that the entire thickness of an aquifer is available for diluting contaminants if nearby wells only draw from a fraction of the thickness of that aquifer unless it is demonstrated that contaminants are mixed throughout the thickness of the aquifer. Examples of simple cases are provided in Figures 1 and 2.

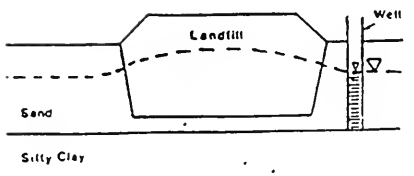

Figure 1

Domestic wells are generally completed in a five metre thick surficial sand. Consider mixing in the saturated thickness of the sand.

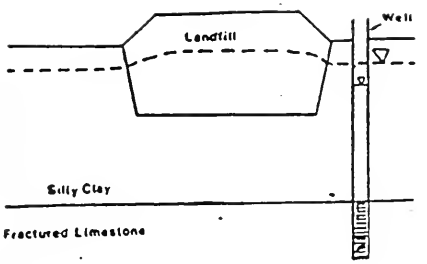

Figure 2

Domestic wells are generally completed in the top six metres of a uniformly fractured carbonate bedrock, although the top 20 metres of the bedrock is productive. In the absence of firm evidence to the contrary, consider mixing in the silty clay and only the top six metres of the bedrock.

As the hydrogeology becomes more complex, as, for example, in Precambrian terrains, or in thick sequences of ice contact deposits, it becomes more difficult to select the proper subsurface units on which to base the estimates of safe impact. Where uncertainty is present, it is suggested that it be resolved by consultation between Ministry Regional staff and the proponent.

3. Mathematical modelling techniques can be used as a tool to help estimate hydrodynamic dispersion and the attenuation of reactive solutes. In particular, rather than assuming a simple case with complete mixing in an underlying aquifer or part of the aquifer, modelling will facilitate the incorporation of dispersion into the estimate for a more sophisticated result.

   Since these models must incorporate assumptions to obtain a manageable solution, the usefulness of such methods for actual predictive estimates is limited. The appropriateness of the models and the assumptions will be considered on a case-by-case basis.

   The Ministry supports the use of reactive contaminant modelling as a part of a predictive monitoring program, but is of the opinion that such models are not reliable unless they are calibrated and verified with ongoing data from the monitoring program. Thus, as previously explained, the Ministry would consider their value limited in a proposal for a new site.

   It should be noted that the benefits of any additional accuracy that may be obtained through the use of a sophisticated model may not be warranted, particularly at small remote sites

where less complex methods may show that a large margin of safety is available.

4. This document does not address contaminants that may not move along a groundwater flow path, such as non-aqueous phase liquids (NAPLs) or liquids more or less dense than water. These liquids and their disposal must be dealt with on a case-by-case basis.

5. In all calculations, possible sources of error should be documented and discussed and some type of "worst case" estimate should be provided (see also Section 4.2). It may be useful to conduct sensitivity analyses by varying the values of the parameters used in the calculations. Calculations should also consider potential changes in groundwater flow brought about by seasonal influences and by off-site groundwater development.

6. A simple estimate of the amount of attenuation by mixing that contaminants from the landfill will undergo on entering a watercourse can be made by comparing the surface area of the drainage basin up stream from the point at which the contaminants will reach the surface waters, to the area of the landfill. In so doing, consideration should be given to the different rates and amounts of recharge through the various types of earth materials in the basin compared to the rate and amount of recharge through the completed landfill cover. In this comparison, it should usually be assumed, in the absence of data to the contrary, that there will be little or no contribution of uncontaminated water during periods of low flow from those parts of the basin where bedrock and other material with small effective porosity are at or within a few feet of the ground surface.

   More sophisticated techniques will be required where the system is more complicated or where the basin divides are not easily defined.

   Where contaminants from landfills discharge to a watercourse, Provincial Water Quality Objectives and associated policies will apply. These are presented in Ministry Policy 15-01, "Water Management Goals, Policies, Objectives, and Implementation Procedures of the Ministry of the Environment", November 1978, Revised, May 1984.

3.0 MONITORING AND CONTINGENCY PLANS

3.1 INTRODUCTION

Any proposals to the Ministry for landfilling must include a monitoring plan and a contingency plan. This section outlines Ministry requirements for monitoring and contingency plans and provides guidance as to how these requirements may be met.

3.2 DEFINITIONS

3.2.1 Monitoring Plan

The monitoring plan is a document which details all construction, operation, maintenance and supervision for a ground or surface water observation network for the routine collection and interpretation of data to supervise a program to protect the environment. The monitoring commences after all, or nearly all, of the site exploration and assessment program has been completed.

Monitoring may range from an extensive program involving the weekly collection and analysis of gas and/or water samples to perhaps no more than a yearly inspection of a landfill for springs or other aesthetic concerns.

3.2.2 Contingency Plan

The contingency plan is a plan for protecting the environment which outlines specific responses to unanticipated, but possible, events. The plan would be implemented if monitoring indicated that some aspect of the design or operation of the waste disposal facility was faulty. The contingency plan describes the "actions" to be taken to address a conceivable, but unexpected, event. The actions, or contingency measures, may range in severity from the proper closure of the site and, where there is no practical alternative, the acceptance of some negative environmental impact, to removing the waste and the associated contaminated soil from a landfill. In some cases, several sequential contingency measures may be outlined in the contingency plan.

An anticipated or expected action, such as the activation of a leachate collection system brought about by the appearance of leachate in a collection tile or a planned modification of a monitoring program, is a part of the operation and maintenance of a

landfill and is not considered to be a contingency measure.

3.3 OBJECTIVES OF MONITORING PLANS AND CONTINGENCY PLANS

The objectives of monitoring and contingency plans are as follows.

1. The monitoring plan will test the accuracy of the hydrogeologic assessment of the site (i.e., the predictions of gas migration and contaminant movement into ground and surface waters) and verify the applicability of any analyses of groundwater flow and contaminant transport that may have been used. Several examples are:

   (a) The rate at which contaminants migrate and attenuate will have been estimated in the site assessment. The monitoring program will, through the collection of several years of data, be the means of testing these estimates and of providing hard data on the rate of contaminant transport and attenuation. An appraisal of these data would be compared to the original assessment and adjustments of the estimated environmental impact of the site or the contingency plan would be implemented as necessary.

   Field data generally suggest that estimates of concentrations of contaminants discharging from landfills are conservative and greater than the concentrations that are actually found. Monitoring may therefore provide data that will justify actions such as the de-activation of leachate and other contaminant control measures.

   (b) An applicant may have based the assessment of a site on an estimated value that the Ministry considers questionable but cannot refute, as, for example, the initial concentration of a particular chemical parameter in the leachate or a recharge rate through a landfill cover. Monitoring data would be gathered during the first year or years of the operation and based on the Ministry assessment of these data, the landfill design would, if necessary, be modified.

2. The monitoring plan may activate various operations at the landfill that are expected. For example, the detection of a specified amount of leachate in a leachate collection system could activate a leachate control system.

3. The monitoring plan will activate contingency measures. For example, unexpected contaminant levels in a monitoring well indicating that unacceptable contaminant concentrations may develop or have developed would trigger a contingency response, such as an increase in monitoring or the proper closure of the landfill or the installation and pumping of purge wells.

   Monitoring installations must provide data that will give sufficient warning (or lead time) of impending unacceptable off-site impacts so that successful contingency measures can be implemented. The monitoring plan must, therefore, consider the configuration of the groundwater flow system as determined in the site assessment, the velocity at which contaminants will move, and the calculations of contaminant attenuation that were made in that assessment.

4. The monitoring plan will evaluate operational activities and contingency measures to ensure that they are performing as required. This will not only provide environmental protection of the site, but will provide transferable data on the performance of various types of contaminant control facilities and on the production and migration of contaminants that will allow the Ministry to improve the regulation of landfills in the Province.

3.4 DEVELOPMENT AND REFINEMENT OF THE MONITORING PLAN

The monitoring plan must be completely or almost completely developed during the site investigation. Before the landfill site is approved the major aspects of the monitoring plan such as the locations, designs, and sampling protocols of the various monitoring installations should be specified and the outline of the plan should be defined. However, it may be necessary to refine some parts of the monitoring plan after the site is operating. Such refinements might include confirming the identity of the critical contaminant and the development of a tiered, long-term monitoring protocol (i.e., the frequency of sampling, the parameters to be sampled, the assessment of sampling data, and the methods by which samples will be collected). Although these subjects would be initially addressed during the site exploration program, on occasion it may be necessary to base final conclusions on the data gathered during the early stages of the monitoring program.

In most cases it is the Ministry preference to initially have an intensive monitoring program with the intent of scaling down the program as supporting data are generated.

3.5 TIME FRAME AND RESPONSIBILITY FOR MONITORING AND CONTINGENCY PLANS

The period of time over which the applicant estimates that monitoring and contingency plan activities will be conducted should be addressed and supporting data and estimates provided in the applicant's submission to the Ministry. The organization(s) responsible for assessing and carrying out these activities during this period and the amount and sources of required resources should also be identified in the applicant's proposal.

To verify that monitoring can be terminated, the collected data must relate contaminant concentration to distance and contaminant concentration to time at a specific monitoring points. It must demonstrate that the contaminant plume is stable or subsiding, and will not expand further, and that contaminant levels in the ground and surface water and the concentration of gases are within accepted limits. When such conditions, (i.e., stability and acceptable limits) have been demonstrated, monitoring programs can be terminated and contingency plans dropped.

3.6 PREDICTIVE MONITORING

Predictive monitoring will generally be required by the Ministry. To meet this requirement the applicant must predict, by technically accepted means, the levels of various contaminants that are anticipated to be present in various monitoring installations at various time intervals.

The Ministry recognizes that to make an accurate prediction of contaminant levels and trends prior to actual landfilling is beyond the limits of our present technology. However, it is always possible to provide estimated values. Comparison of the predicted and the actual values obtained from the monitoring program will allow the Ministry to judge the level to which the hydrogeologic system at the site is understood. A secondary benefit of predictive monitoring is that it necessitates the routine collection and assessment of incoming monitoring data and an organized periodic review of the monitoring results.

In conjunction with providing a prediction of the contaminant levels and their trends in various monitoring wells, the applicant should also specify:

a. The levels of contaminants in particular wells which would indicate that the design of the landfill may fail, and

b. The triggering levels which would activate various contingency and operational activities.

3.7 CONSTRUCTION OF MONITORING INSTALLATIONS TO MEASURE OFF-SITE IMPACT

As discussed in Section 2.2, the subsurface unit(s) that must be protected to meet the requirements of the "Reasonable Use" policy must be identified by the applicant. Groundwater monitoring data at or near this unit(s) will be required in order to determine if the site is meeting these requirements. The following points should be noted.

1. Although the Ministry may not judge the acceptability of a contaminant discharge on the basis of contaminant levels in the most contaminated unit in the subsurface, it will generally be necessary for monitoring wells to be placed within those units in the groundwater flow system where it is expected that the contaminant plume will have its greatest impact on groundwater quality.

2. In most cases (except as noted below) subsurface units should be monitored with individual "aquifer specific" wells. However, where the hydrogeologic system is complex, monitoring wells with relatively long screens and sand packs crossing a series of thin permeable units may be appropriate and water quality data may be "averaged" in this manner.

3. Monitoring wells should be placed to take into consideration any density contrasts between groundwater and contaminants. Thick unconfined aquifers will present the most difficulty in establishing the effect of contaminant density and in correctly setting the depth of monitoring wells.

4. Monitoring wells require particularly careful positioning in fractured media in order to properly assess the impact of the landfill.

5. The possibility of hydraulic connection between aquifers within and beyond the boundary of a waste disposal site should be considered in the location and construction of site boundary monitoring wells.

4.0 THE ESTABLISHMENT OF SAFETY MARGINS IN THE ASSESSMENT OF LANDFILL SITES

4.1 INTRODUCTION

Section 2.4,b of the "Reasonable Use" document, Policy 15-08, discusses the need for establishing a safety margin to account for uncertainty in the estimate of contaminant discharge and the consequences of failure of a waste disposal facility. The Ministry considers this step to be particularly important because it allows the Ministry to present to a proponent of a landfill or to a hearing board the Ministry view of local conditions and concerns. It is most useful to discuss safety margins with proponents as early as possible in the site selection and evaluation process.

There are two approaches available for presenting safety margins; a quantitative approach, and a qualitative approach. The qualitative approach addresses the hazard posed by a facility using terms such as "high risk", "low risk", etc. The quantitative approach attempts to describe the "risk" in numerical terms that can be incorporated into the site assessment. There is a danger that quantitative safety margins will be viewed as having an unwarranted amount of credibility. For this reason, qualitative terms were considered. However, it was felt that numerical safety margins, despite their disadvantages are more useful to a hearing board. Nevertheless there will be cases where qualitative safety margins will be most appropriate and should be used in site assessments rather than the quantitative system described here.

Safety margins for the following concerns should be addressed in all landfill site assessments.

(a) The accuracy of the calculation.
(b) The value of the resource.
(c) The consequences of failure, and
(d) The characteristics of the waste, and the contaminants that are produced.

Numerical values can be assigned to each of the four listed safety margins, and although these will be somewhat arbitrary, and only a) the accuracy of the calculation can be truly quantitative, they will reflect the level of concern.

The safety margins that are applied to each of these factors are multiplied to give a total safety margin that is applied to the site. For example, if the acceptable increase of the critical contaminant at the point of concern is x, and the

safety margins for the accuracy of the calculation, the value of the resource, the consequences of failure, and the characteristics of the waste are, a, b, c, and d, respectively, the site would be designed so that the concentration of the critical contaminant at the point of concern is less than x/abcd.

A judgement of the total safety margin for a site will be made by the Director of the Ministry Regional Office.

The establishment of safety margins will make it more difficult for applicants to obtain Ministry support for landfill sites in environmental settings that are difficult to assess, or where failure will have serious environmental consequences. The effect of safety margins will be to downsize disposal areas, and to increase buffer areas and will lead to the rejection of marginal sites where risks are high.

4.2 THE ACCURACY OF THE CALCULATIONS

A quantitative assessment of the potential errors in the values of the parameters and in the calculations that have been used to arrive at estimates of contaminant concentrations at the site boundary should be included in submissions to the Ministry. This estimate is similar to and could serve as a "worst case" assessment.

Generally, the largest sources of error are in the calculations involving hydraulic conductivity and dispersivity or in the estimates of the attenuation of reactive contaminants. These estimates will seldom be accurate to within a factor of 5X, and may be in error by considerably larger amounts. Therefore, assessments of contaminant attenuation that do not consider these factors, such as an assessment based on the attenuation in an existing stable contaminant plume, are more reliable. A lower safety margin is required when conservative values are used in a site assessment or when the results of estimates of potential contaminant levels that have been made using several techniques compare favourably. Thus, a potential error in hydraulic conductivity of 5X may not require a safety margin of 5X.

Designs for landfill sites in complex hydrogeologic environments will require a relatively high safety margin, because such sites are much more difficult to assess than sites in relatively simple hydrogeological environments.

The characteristics of the contaminants are also a factor in establishing this safety margin. For example, the assessment of the threat posed by contaminants that do not

follow groundwater flow paths or change in composition during migration may be very uncertain.

This safety margin may be reduced if monitoring data subsequently verify the accuracy of the calculations. If required, provisions may be made in the Certificate of Approval to consider modifications in the design or size of a landfill on this basis.

4.3 THE VALUE OF THE RESOURCE

Sites having the potential to affect major or sole- source water resources require greater safety margins (perhaps on the order of 2X) than sites in other environments. Sites in settings where the potential for impacting water resources is low could have a safety margin of 1X.

4.4 THE CONSEQUENCES OF FAILURE

Landfill sites with a potential to affect water supplies serving large populations (e.g., close to a municipal well), sites with the potential to affect recreational water bodies, or sites that may have an unusual impact on wildlife, etc., will require a safety margin perhaps on the order of 2X. The costs and effectiveness of the monitoring plan and the contingency plan to remedy any failure should be a consideration in assigning this safety margin. Sites in remote areas where there is little groundwater use would generally have a safety margin of 1X.

In judging the consequences of failure, consideration should also be given to the potential for the wastes and the contaminants produced from them to degrade and the length of time that the site will be a threat to the environment.

4.5 THE CHARACTERISTICS OF THE WASTE AND THE CONTAMINANTS THAT ARE PRODUCED

A safety margin should be incorporated to address the health hazard associated with a particular contaminant or waste. For example, a contaminant that affects health when it is at a concentration in the parts per billion or parts per trillion range and is not detectable at these low levels by taste or odour, would require a large margin of safety (perhaps on the order of 3X) as compensation for this particular concern. On the other hand, a landfill consisting of, for example, wood waste or domestic refuse, would require a safety margin of 1X.

4.6 GENERAL CONSIDERATIONS

In submitting a proposal, the Applicant will be expected to provide a quantitative estimate of the error involved in the calculation of contaminant levels, and should address, qualitatively (i.e., present a position), the value of the resource that might be impacted, the consequences of failure, and the toxicity of the waste. The Regional Office of the Ministry will provide an opinion on the applicant's estimate of the accuracy of the calculations, and will require safety margins as necessary to deal with this estimate, the value of the resource, the consequences of failure and the toxicity of the waste.

The Ministry does not consider that the incorporation or duplication of engineered contaminant control facilities will increase the safety margin at a site, unless these are dealt with in the context of both their short-term and their long-term impact on contaminant discharge, and consideration is given to the service life of the control facilities in terms of the time over which the waste will pose a hazard and contaminants will be produced. Engineered facilities at landfills are addressed in Policy 14-15.

4.7 SUMMARY

Large safety margins will be required by the Ministry for landfill sites in complex hydrogeologic environments, in environments that are particularly sensitive to contamination, or where the risk of failure is not acceptable. Large safety margins will also be used to discourage the landfilling of wastes which produce contaminants that, because of their toxicity and resistance to degradation, should not be buried in the ground.

5.0 THE CONTROL OF GROUNDWATER DEVELOPMENT IN THE VICINITY OF LANDFILL SITES

5.1 INTRODUCTION

The assessment of the potential impact of a proposed waste disposal operation and, in some cases, the design of monitoring programs must assume that there will be some degree of stability in the groundwater flow system. Thus, it must be possible for the Ministry to exert some control over groundwater development in the vicinity of waste disposal sites. Fortunately, environments where the potential for groundwater development is high and where the necessity for such control is most probable, have the least potential to attenuate contaminants and thus are not well suited to waste disposal. Therefore, this is not likely to be a concern at proposed sites. However, it may be necessary to consider the control of groundwater development at sites requesting permits for expansion or at sites where contaminant discharges have or are likely to threaten the environment.

The following section describes the legal tools that are available. Their use would be at the discretion of the Director.

5.2 LEGAL FRAMEWORK

The tools available to the Ministry to control local groundwater development appear in the Ontario Water Resources Act in Section 23, 23a, 23b and Section 21(4). None of these sections have been used to date to facilitate the approval of landfills or the control of existing contamination.

5.2.1 Section 23

Section 23 of the Act (part of the 1981 amendments) prohibits the construction of a well in an area designated by the regulations unless a permit is obtained from the Director. Section 23b lists the reasons a Director may use to refuse a permit or to issue one with terms and conditions. Several of the available reasons would seem appropriate, particularly clause (d), "likely ... impairment of the quality of ... land ... for any use that is being ... made of it". If a permit is to be issued, it appears that terms and conditions could address the precise location, the well construction technique and the well structure. Several things in the Section also suggest that terms and conditions could also address the quantity to be taken or at least the maximum quantity

that the well, including pumps, etc., could be designed to take.

The specific wording of Sections 23, 23a, and 23b is as follows:

Section 23 - No person shall construct a well in an area designated by the regulations except under and in accordance with a well construction permit issued by a Director.

Section 23a - Subject to Section 23b, any person who applies in accordance with this Act and the regulations for a well construction permit and who pays the prescribed fee is entitled to be issued the permit.

Section 23b - A Director may refuse to issue or to renew or may revoke a well construction permit, may impose terms and conditions in issuing or renewing or after issuing or renewing a well construction permit and may alter the terms and conditions of a well construction permit that has been issued or renewed where the Director is of the opinion, upon reasonable and probable grounds, that,

(b) there is or is likely to be danger to the health or safety of any person;

(d) there is or is likely to be impairment of the quality of any air, land or water for any use that is being or is likely to be made of it;

(e) there is or is likely to be reduction of the quantity of water available for any use that is being or is likely to be made of it;

(g) any property or plant or animal life is or is likely to be rendered, directly or indirectly, unfit for use by man;

(i) there is or is likely to be interference with the normal conduct of any business; or

(j) there is a breach of a term or condition of the permit.

A regulation is necessary to designate the areas where a permit is desired. It could simply state that a permit is necessary for a well within so many metres of a landfill site or a landfill site of a particular class, but it is likely that site specific consideration is necessary. Accordingly, the

regulation would simply say: The following areas are designated for the purpose of S.22 of the Act. This would be followed by a list of specific areas surrounding landfills.

The definition of the area, together with any other requirements as, for example, special well construction procedures and a request for designation should come from the proponent of the landfill and be defended at the waste disposal site hearing. Upon approval of the site, the regulation would be amended to add the new location to the list of designated areas. The proponent must be cautioned that any imposition by the Director of conditions on a water well permit is subject to appeal and the Director's decision (intended to preserve stability in the groundwater flow system) could be overturned.

5.2.2 Section 21(4)

Once a landfill site is operating and a well has been legally established in the vicinity, ongoing control of the amount of water which may be taken would be achieved under the water taking permit program. This program does not apply to takings under 50,000 litres a day or to takings for domestic or farm purposes (other than irrigation of crops for sale) or to fire fighting. However, where an exempt taking interferes with a "public or private interest in any water" the Director may require that a water taking permit be obtained anyway (Section 21[4]). There is also provision for the Director to step in and require corrective action where there is interference with "any public or private interest in any water" as a result of the leaking of water from a well or the diversion of water by means of a hole or excavation not intended for taking water (Section 21[7]). Once again, actions taken by the Director under these sections are subject to appeal.